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Cognitive Task Demands and Discourse Performance after Traumatic Brain Injury

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Abstract

Background—Social communication problems are common in adults with traumatic brain injury (TBI), particularly problems in spoken discourse. Social communication problems are thought to reflect underlying cognitive impairments.

Aims—To measure the contribution of two cognitive processes, executive functioning (EF) and theory of mind (ToM), to the communication of adults with TBI, and to investigate the relationships between discourse performance and potential communication partners' perceptions.

Methods & Procedures—Twenty-one adults with moderate-to-severe TBI and 23 uninjured adults completed a discourse task in which EF and ToM demands were manipulated across three conditions: baseline, High-EF, and High-ToM. Dependent variables were fluency (for EFs), number of mental state terms (MSTs, for ToM), and speech rate. Discourse from High-EF/ToM conditions was judged by naïve raters for social acceptability.

Outcomes & Results—The TBI group produced significantly fewer MSTs than the comparison group across conditions and also spoke at a slower rate, and there were significant effects of condition on both measures (MST: High EF < baseline = High-ToM; Speech rate: High-EF < High-ToM < baseline). There were no significant between-groups differences in fluency or interaction of fluency with condition. MST use and fluency were associated with social acceptability ratings.

Conclusions & Implications—Results added further evidence of social communication problems in adults with TBI and demonstrated that discourse behaviors may negatively affect how a speaker is perceived. Results also indicated that task manipulations can affect discourse performance, suggesting that general cognitive demands may influence social communication after TBI.

Keywords

Traumatic brain injury; social communication; theory of mind; executive function; speech language pathology

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Background

Many individuals with traumatic brain injury (TBI) have chronic and debilitating communication problems (Dahlberg *et al.* 2006, Douglas 2010). These problems are most commonly characterized as impairments in the ability to communicate appropriately and effectively across contexts (Dahlberg *et al.* 2006, Douglas 2010, Togher and Hand 1998). The set of skills that facilitates appropriate communication has been termed *pragmatics* (Bates, Hamby and Zurif 1983), also referred to as social communication skills. In adults with TBI, social communication deficits may include impaired comprehension of indirect language (Bosco *et al.* 2015, Channon and Watts 2003, Muller *et al.* 2010), poor organization of spoken and written discourse (Coelho *et al.* 2013, Ghayoumi *et al.* 2015, Rousseaux, Vérigneaux and Kozlowski 2010); giving too much or too little information to their communication partners (Coelho *et al.* 2002, Moran, Kirk and Powell 2012); and failing to adjust their language in response to the partner (Togher and Hand 1998) or task (Byom and Turkstra 2012). Overall, adults with TBI have been rated as less rewarding, appropriate, and interesting conversation partners than their peers (Bond and Godrey 1997).

Social communication problems associated with TBI are thought to reflect underlying cognitive rather than linguistic impairments (Prigatano, Roueche and Fordyce 1985). Successful social interaction is cognitively demanding and requires individuals to plan and use language flexibly across contexts, inhibit inappropriate responses, and continually update representations in working memory as social cues change over time. Execution of such behaviors places high demands on executive functions (EFs). EFs are a set of discrete, but related, cognitive processes that facilitate problem-solving and goal-oriented behavior (Miyake *et al.* 2000). EF deficits have been robustly documented in individuals with TBI (Channon and Watts 2003, McDonald *et al.* 2014, Muller *et al.* 2010) and there is some evidence that EF impairments are associated with social communication problems such as inaccurate or poorly structured discourse (Lê *et al.* 2014, Marini, Zennin and Galetto 2014), poor comprehension of social implicature (Channon and Watts 2003), and perceived social communication problems in daily life (Douglas 2010). Other studies, however, have found weak or non-significant links between EFs and social communication (Coelho 2002, Marini *et al.* 2011, McDonald *et al.* 2006). These mixed findings might reflect the broad range of ways that EFs and social communication have been operationalized and measured across experiments, or might mean the relation of EF impairments to social communication problems is correlational rather than causal. In either case, the degree to which the EF account explains social communication problems in adults with TBI remains unclear.

An alternative to the EF account of TBI-related social communication deficits is the Social Inference Hypothesis (Martin and McDonald 2003). This hypothesis holds that social communication deficits reflect underlying impairments in Theory of Mind (ToM), the ability to reason about the mental states of others to predict their behavior (Premack and Woodruff 1978). ToM deficits have been well documented in adults with moderate-to-severe TBI (for review see (Martín-Rodríguez and León-Carrión 2010), however evidence of links between ToM impairments and poor social communication in adults with TBI is limited. Stronach and Turskstra (2008) found that adolescents with TBI who had low ToM test scores used fewer ToM-related words in conversation than did both typically developing adolescents and adolescents with TBI who had higher ToM test scores. Also, McDonald and Flanagan (2004) found that the ability to reason about others' intentions (second-order ToM) significantly predicted how accurately participants with severe TBI understood non-literal statements in conversation. By contrast, however, Milders *et al.* (2008) found no significant association between ToM scores of adults with TBI and close others' ratings of social communication in everyday life. Thus, findings are mixed.

In sum, efforts to attribute poor social communication after TBI to impairments in either EF or ToM have, so far, proven inconclusive. An important limitation of these studies is the reliance on correlations between scores on ToM and EF tests and social communication measures. This correlational approach relies on the validity of available ToM and EF tasks, and both have been criticized for construct-related confounds and lack of ecological validity (Burgess *et al.* 1998, Byom and Mutlu 2013). Many ToM tasks carry significant linguistic and cognitive demands over and above the need to make ToM judgments (Muller *et al* 2010), making it difficult to determine what aspect of performance is linked to social communication. Further, the second-person nature of most ToM tasks limits the extent to which resulting scores can inform predictions about ToM in daily life (Byom and Mutlu 2013). Similarly, standard EF tests provide explicit structure for carrying out assigned tasks while limiting distractions that might occur in everyday life (Burgess *et al.* 1998). Simply, the nature of such tasks limits their ability to capture the kinds of ToM and EF demands speakers encounter in daily communication.

Rather than relying on correlations with standardized tests, a stronger method for examining the relationships between cognitive processes and social communication is to manipulate the ToM and EF demands of the communication task itself. McDonald and colleagues (2014) employed this approach by manipulating cognitive flexibility and inhibition demands in a social communication task, in this case a discourse task in which participants with severe TBI discussed the features of holiday resorts, either from their own perspective (low ToM) or from that of a hypothetical character (high ToM). Results indicated that poor discourse performance in the high ToM conditions could be attributed, in part, to the task's cognitive flexibility demands. Participants with TBI also had marked impairment when asked to inhibit their own thoughts in order to discuss resorts from another's perspective (McDonald *et al.* 2014). One limitation of this study, however was the main discourse measure used: the number of relevant details described. Generating appropriate details for each condition likely engaged several cognitive and linguistic processes in addition to ToM and EF, making it difficult to determine the specific processes that contributed to performance.

In this study we measured two discourse features: mental state terms (MSTs), which have been linked to ToM, and dysfluencies, which have been linked to EFs. MSTs are words that reflect thoughts, feelings, and desires (Bretherton and Beeghly 1982). MST use implies an understanding of the underlying mental states of the speaker and others to which he or she refers (Stronach and Turkstra 2008). MST use has been linked to ToM development in children (Adrian *et al.* 2005), and individuals with TBI, for whom ToM impairment is common, have been found to use MSTs less frequently than their uninjured peers (Byom and Turkstra 2012, Stronach and Turkstra 2008).

Dysfluencies are communication behaviors that disrupt the flow of discourse and in the absence of aphasia or stuttering, their frequency is associated with EF in communication (Fagan 1982, Turkstra *et al.* 2004). As described previously, EFs are vulnerable to TBI and individuals with TBI have been found to produce more dysfluent discourse than peers without TBI (Ghayoumi *et al.* 2015, Moran, Kirk and Powell 2012).

Aims and Hypotheses

The aim of this exploratory study was to investigate the role of EF and ToM in social communication after TBI. Toward this aim, we measured MSTs and dysfluencies in a naturalistic communication task. Participants discussed controversial issues, and we manipulated EF demand by imposing constraints on verbal output, and ToM demand by requiring participants to shift perspective from their own to that of another person. We expected participants to be more dysfluent when EF demands were increased, and use more MSTs when ToM demands were increased. Based on evidence of ToM and EF impairments after TBI, we further hypothesized that across conditions, participants with TBI would use fewer MSTs and would be more dysfluent than age- and education-matched peers without TBI. Group effects were expected to be condition-dependent, however, with the TBI group showing discourse differences only in high-demand conditions. Specifically, we predicted that the TBI group would be less able than the comparison participant (CP) group to meet high ToM demands during conversation, leading to less frequent MST use in a high, but not a low-demand condition. Similarly, the TBI group was expected to be more dysfluent than the CP group, but only when EF demands were high.

An additional aim was to investigate the impact of dysfluency and MST use on perceptions of potential communication partners. Prior research has shown that untrained raters can reliably judge brief excerpts of social behavior, termed “thin slices,” across multiple communication modalities, including discourse transcripts (for review see Ambady, Bernieri, and Richeson 2000). In the TBI literature, Jones and Turkstra (2011) used a thin slice approach to investigate associations between charisma of adults with TBI and social acceptability, finding that markers of charisma (e.g., speech rate, gesture use) were significantly associated with the likelihood that a rater would want to have a conversation with the speaker. While others have provided evidence that listeners judge the discourse of adults with TBI negatively (Bond and Godrey 1997), further work is needed to identify which discourse features contribute to these judgments. We predicted that raters would perceive both less fluent discourse and also discourse with fewer MSTs as less acceptable and appropriate, regardless of participant group.

Methods and Procedures

Participants

Twenty-five adults with moderate-to-severe TBI (15 men, 10 women) and 23 adults with no history of TBI (12 men, 11 women) were recruited from community sources in the upper Midwest region of the United States. Inclusion criteria for individuals with TBI were: a) age 21–60 years at time of testing; b) moderate-to-severe TBI, defined as a Glasgow Coma Scale score of 13 or below at hospital admission, post-traumatic amnesia (PTA) of at least 24 hours, or abnormal, injury-related neuroimaging findings; c) at least one year post-injury; d) oral language skills sufficient for discourse, as defined by Western Aphasia Battery (Kertesz 1982) Aphasia Quotient scores greater than 93.8; e) speech intelligibility sufficient for conversation with an unfamiliar partner, as determined by a trained speech-language pathologist; f) self-report of English as a primary language; g) no pre-injury history of language or learning disability, special education services, gifted status, or neurological or psychological diagnosis, per participant report. Two male participants with TBI failed to meet these inclusion criteria, one due to his age at time of testing, and the other due to an Aphasia Quotient lower than 93.8. These participants' data were excluded from analysis. Data from a third male participant with TBI were excluded due to video equipment failure during the discourse task and data from one female participant with TBI were excluded because she only completed one topic in the experimental discourse task due to anxiety and thus produced a limited amount of discourse. Thus, the final TBI group was comprised of 21 participants (12 males) with a median age of 33 years (range: 21–59) and a median 14 years of education (range: 12–18). Participants were between 1.4 and 40 years post-injury (median = 8 years) and injury causes included motor vehicle accidents (n = 16), recreational accidents (n = 3), falls (n = 1), and assault (n = 1).

Participants in the CP group were aged 21–57 years (median = 28) with a median education of 16 years (range: 12–18). Participants in the CP group reported no history of brain injury, spoke English as a primary language, and denied a history of language or learning disability, special education services, gifted status, or neurological or psychological diagnosis.

Participants were paid $10 per hour for their time, with the exception of one participant with TBI who received extra course credit for a portion of his participation and was paid $10 per hour for the remaining time he contributed.

Fifty-one undergraduate students (six males) served as perceptual raters for the TBI group's discourse samples and an additional 38 undergraduate students (four males) rated discourse samples from the CP group. To comply with institutional review board regulations, sex was the only demographic information collected from raters. Perceptual raters earned extra course credit for participating.

Discourse Task

Participants first completed a 5-minute, video-recorded warm-up conversation with the investigator to become familiar with the environment and accommodate to the presence of the camera. During the warm-up conversation, the investigator asked questions modified from the superficial question list of the Relationship Closeness Induction Task (Byom and Turkstra 2012, Sedikides *et al.* 1999), a task designed to promote engagement with novel communication partners. At the end of the warm-up conversation, the experimental portion of the task began.

For the discourse task, participants discussed five controversial social issues: global warming legislation, U.S. foreign aid spending, animal research, the USA Patriot Act, and legalized assisted suicide. This method has been used previously to engage adults in social interaction (Ybarra *et al.* 2008), and the use of multiple topics addressed the potential for some topics to be more engaging or familiar to participants than others. Topics were selected based on pilot data from 63 undergraduate students, who rated the strength of their opinions on nine issues. From these, the five issues with the highest average ratings were selected for the study. As in Ybarra and colleagues (2008), participants read short informational paragraphs that described basic aspects of each topic. Informational paragraphs remained in the participant's view for the duration of the task. After reading each paragraph, participants answered five comprehension-check questions. All participants in the CP group and 19 of 21 participants in the TBI group answered all comprehension check questions correctly. Of the two participants with TBI who made comprehension check errors, one participant made two errors, the other one error. In those cases, the correct answers were provided to the participant before continuing with that topic. Following the comprehension-check questions, participants discussed each topic in three experimental conditions: baseline, High-ToM, and High-EF, described below. Participants completed the baseline condition first for each topic, to identify their opinions, then the order of the High-EF and High-ToM conditions and topic order were randomized across participants. During the discourse task, the investigator served as an audience only, providing only naturalistic back-channel responses (e.g., nodding).

Discourse Task

Baseline Condition—In the baseline condition, participants described why they thought each issue was good or bad. If participants indicated they had mixed feelings about an issue, they were asked to choose the side for which they felt most strongly. If participants could not choose a side, that topic was skipped for all three conditions. The baseline condition served as a baseline for the High-ToM and -EF conditions because participants had planning time, were only asked to consider their own perspective on each issue, and were free to say whatever they chose.

High-EF Condition—In the High-EF condition, participants described why they thought each issue was good or bad, but this time without using the words "and" and "the." This type of manipulation has been reported to tax EF resources in previous research (Schmeichel 2007). As in the baseline condition, participants were given as much time as they needed to formulate their arguments. The prohibited words were written down and remained in participants' view throughout the condition, to limit potential confounds related to memory impairments.

High-ToM Condition—The High-ToM condition required participants to discuss their thoughts on why someone might hold the opposite opinion on each of the topics. To make this perspective-shift concrete, participants were given a brief description of a fictional character who held the opposite view. For example, if a participant argued in favor of global warming legislation in the baseline condition, he or she was given the example of "the owner of a semi-truck company" as someone who might argue against restricted fossil fuel use. The character description remained in participants' view throughout the condition.

Not all participants completed all five topics due to reluctance to take a side (CP: 6 participants, 1 topic each), limited testing time (TBI: 1 participant, 2 topics; CP: 1 participant; 2 topics), failure to follow condition instructions (TBI: 2 participants, 1 topic each), fatigue (TBI: 3 participants, 2 topics each), agitation (TBI: 1 participant, 2 topics), and camera failure (TBI: 1 participant, 2 topics). In those cases, data from all three conditions of that topic were excluded.

Manipulation checks—There were two manipulation checks. First, to verify that participants were exerting more executive control for the High-EF condition, they rated how much they had to think about what they were saying after completion of the baseline and High-EF conditions, using a 5-point Likert scale (participant had to think 1 = "very much"; 5 = "not at all"). Second, to ensure that participants were thinking of someone else's views during the High-ToM condition, participants rated on a 5-point Likert scale the degree to which they were thinking about their own perspective while completing the baseline and High-ToM conditions (participant was thinking about his/her own opinion 1 = "very much"; 5 = "not at all"). One-tailed Wilcoxon Signed Ranks tests indicated that participants in both groups reported that they were thinking significantly less about their own opinion in the High-ToM condition relative to the baseline condition (TBI, $Z = 1.75$, $p = 0.04$; CP, $Z = 6.30$, $p < 0.01$). Both groups also reported having to think more about what they were saying in the High-EF condition than in the baseline condition (TBI, $Z = -3.45$, $p < 0.01$, CP $Z = -6.61$, $p < 0.01$).

We also tested whether the groups differed in their opinions of any of the topics, which could have affected the demands associated with considering a differing opinion. Participants rated their opinions for each topic on a 5-point Likert-type scale (1 = very opposed; 3 = neutral; 5 = very in favor). Separate Mann-Whitney U tests on mean ranks were conducted for each topic, indicating that groups did not differ in their opinions on any of the five topics (global warming: U = 143.5, $p = 0.42$; patriot act: U = 102.00, $p = 0.06$; foreign aid: U = 130.00, $p = 0.23$; assisted suicide: U = 129.00, $p = 0.50$; animal research: U = 131.00, $p = .37$).

Discourse analysis—Discourse samples were transcribed orthographically by a trained research assistant using Codes for the Human Analysis of Transcripts (CHAT) coding conventions and Computerized Language Analysis (CLAN) software (MacWhinney 2000). Samples were segmented into terminable units (t-units), defined as one independent clause and any subordinate clauses. Inter-rater reliability was calculated for t-unit segmentation on 11.11% of all transcripts, and was 95.17%. To characterize the discourse samples, CLAN was used to calculate the total number of words and type-token ratio (TTR; total number of different words divided by total words) for each participant.

The dependent variable for EF was the number of dysfluencies per t-unit. Dysfluencies or mazes were filled pauses (e.g., um, uh), unfilled pauses longer than 3 seconds, revisions, repetitions, reformulations, or abandoned utterances. The dependent variable for ToM was number of MSTs per t-unit. MSTs were identified using lists of MSTs used by adults and adolescents in previous studies (Byom and Turkstra 2012, Stronach and Turkstra 2008). Any other words not included in these lists, but that reflected a thought, feeling, belief, or opinion were identified as MSTs. Inter-rater agreement on 11.11% of all transcripts was 97.15% for dysfluency identification and 91.99% for MST identification. Disagreements were resolved through discussion until consensus was reached.

Secondary Analysis—Upon review of the discourse samples it appeared that participants spoke more slowly during the high-demand conditions. Because this behavior could represent a strategy that might differ between groups, we compared speech rates across groups and conditions. Speech rates for each participant in each condition were calculated by dividing the total number words spoken (counted according to the method described in Nicholas and Brookshire 1993) by total speaking time, in minutes. Videos from two participants in the CP group were damaged at the time of speech rate analysis, thus these participants' data were not available for this analysis. Because dysarthria could also account for reduced speech rate, the TBI group's discourse samples were reviewed independently for the presence or absence of dysarthric speech characteristics by two trained graduate students in speech language pathology, who were blinded to the study aims and group membership, and a speech language pathology clinical fellow (the first author). All raters agreed that eighteen of the 21 participants with TBI did not display any form of dysarthria. Two raters judged the speech of all 21 participants as being free of dysarthric features, while one rater judged three participants with TBI to have mildly dysarthric speech, one of whom, was judged to have only dysarthric features related to vocal quality. One of these three participants spoke with a rapid speech rate in the baseline condition, but none of the other discourse samples from these participants were outliers in speech rate. Further, removal of these participants' data from the speech rate analyses did not affect the results so they were included in the final analysis.

Perceptual Ratings

Naïve raters blinded to the study aims and participant group membership read transcribed discourse samples from the High-ToM and High-EF conditions via web-based Qualtrics© survey software (2013) version 43,051. We used transcripts rather than video clips to protect participants' identities and eliminate the possibility that speakers' non-verbal characteristics (e.g., limb motor impairments or scars) influenced ratings. Each rater read 50 randomly selected transcripts and rated each on a 4-point Likert-type scale for 1) appropriateness of the comments to the topic (1 = very appropriate, 4 = very inappropriate), and 2) likelihood that they would want to have a conversation with the speaker (social acceptability; 1 = very likely, 4 = very unlikely). Each transcript was judged by at least five raters and average ratings for High-EF and High-ToM discourse samples were calculated for each participant. Two participants' discourse samples were not rated because of technical problems, and one participant's discourse in the high-ToM condition was excluded because it contained profanity.

For both experimental groups, appropriateness ratings were significantly correlated with social acceptability ratings for the High-ToM, TBI: $r = 0.71$, $n = 19$, $p = 0.01$; CP: $r = 0.87$, $n = 22$, $p < 0.01$; and High-EF conditions, TBI: $r = 0.92$, $n = 20$, $p < 0.01$; CP: $r = 0.62$, $n = 22$, $p = 0.02$. Given the exploratory nature of this study however, results from both appropriateness and acceptability ratings are reported.

Cognitive Assessment

To characterize the sample, participants completed a battery of cognitive tests: Processing Speed Index of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler

1997); California Verbal Learning Test (Delis *et al.* 2000); Trails Test, and Color-Word Interference Test, both of the Delis-Kaplan Executive Function Systems (D-KEFS; Delis, Kaplan and Kramer 2001). ToM was assessed with the Video Social Inference Task (VSIT; Turkstra 2008).

Procedure

All participants gave informed consent or assent depending on guardianship status before beginning the experimental protocol. Demographic information was collected during a structured interview then participants completed the standardized tests and experimental tasks. Task order was randomized for each participant and all procedures were approved by the relevant institutional review board.

Analysis

For descriptive purposes, t-tests were conducted to compare groups on demographic variables and cognitive test scores. To rule out potential confounds due to differences in linguistic diversity and productivity, we compared TTR and total number of words across groups and conditions using mixed analyses of variance (ANOVAs). We tested the hypotheses that MST and dysfluency rates differed across groups (TBI vs. CP) and conditions (baseline, High-ToM, High-EF) using separate mixed ANOVAs. A mixed ANOVA was also conducted on speech rate data to test whether there were group, condition, or interaction effects. Planned post-hoc t-tests were used to compare MST, dysfluency, and speech rates across the three conditions as indicated by ANOVA results. To account for multiple comparisons of MST, dysfluency, and speech rates, Bonferroni corrections were applied.

Associations between MST and dysfluency rates, and perceptual ratings were tested separately for TBI and CP groups using Pearson product-moment correlations.

Prior to testing the study hypotheses, we inspected the distributions of MSTs and dysfluency, finding similar patterns across all five topics for both groups, thus data were collapsed across topics. Distributions were further examined for normality and the presence of outliers. The distributions for MST use, dysfluency rate, and speech rate were skewed so square root transformations were applied to each. Outliers were defined as data points falling 1.5 times the inter-quartile range below the 1st quartile or above the 3rd quartile. Per this rule 17 of 396 data points were identified as outliers. Excluding outliers did not affect the results of the ANOVAs, however, so outliers were included in the final analyses. Correlation analyses were more sensitive to the inclusion of outliers so results with and without outliers are reported.

All analyses were conducted using IBM© SPSS© Statistics for Macintosh, Version 22.0.0 (IBM 2013).

Results

Participant groups were similar in age (t(42) = 0.96, $p = 0.34$), years of education (t(42) = −1.05, $p = 0.30$), and number of males and females (Fisher's Exact Test, $p = 0.77$). The TBI group scored significantly lower than the CP group on tests of information processing speed and EF (see table 1).

Discourse Task

Discourse data are shown in table 2. The experimental groups produced a similar number of words across conditions, F(1,42) = 1.18, $p = 0.28$. There was a significant main effect of condition on productivity, F(1.87, 78.66) = 17.12, $p < 0.01$, which remained after adjusting degrees of freedom for violation of sphericity using Hyunh-Feldt correction ($\varepsilon = 0.94$, $p = 0.05$). Participants used fewer words in the High-EF condition than in the baseline (t(43) = 4.92, $p < 0.01$) and High-ToM (t(43) = 4.40, $p < 0.01$) conditions, which were similar (t(43) = 1.76, $p = 0.09$). There was not a significant group by condition interaction for number of words produced, F(1.87, 78.66) = 0.27, $p = 0.75$. TBI and CP groups did not differ in TTR, F(1,42) = 0.01, $p = 0.95$. After adjusting degrees of freedom for violation of sphericity using Greenhouse-Geisser correction ($\varepsilon = 0.53$, $p < 0.01$) there was no condition effect on TTR, F(1.06, 44.55) = 0.81, $p = 0.38$, nor was there a significant group by condition interaction, F(1.06, 44.55) = 0.90, $p = 0.35$.

Discourse and ToM demand—Results indicated that there was a significant group effect, F(1, 42) = 11.05, $p < 0.01$, as the TBI group used significantly fewer MST per t-unit than the CP group. There was a significant effect of condition, F(2, 84) = 7.37, $p < 0.01$. Pair-wise t-tests indicated that MST frequency was similar in the baseline and High-ToM conditions (t(43) = −0.10, $p = 0.92$, $d = .05$). Participants, however, used significantly fewer MST per t-unit in the High-EF condition than in the baseline (t(43) = 3.19, $p < 0.01$, $d = 0.48$) and High-ToM conditions (t(43) = 3.16, $p < 0.01$, $d = 0.56$). A significant group by condition interaction was not supported, F(2, 84) = 1.29, $p = 0.28$.

Discourse and EF demand—There was no significant group effect, F(1,42) = 0.01, $p = 0.94$, condition effect, F(2,84) = 0.26, $p = 0.77$; or group-by-condition interaction, F(2,84) = 0.03, $p = 0.97$ on dysfluency rate.

Speech Rate and Cognitive Demand—Analysis revealed that the TBI group had a significantly slower speech rate than the CP group, F(1,40) = 6.93, $p = 0.01$. After adjusting degrees of freedom for sphercity ($\varepsilon = 0.90$, $p = 0.01$) using Huynh-Feldt estimates, there was a significant condition effect for speech rate, F(1.80, 71.82) = 77.85, $p < 0.01$. Paired t-tests indicated that, participants had a faster speech rate in the baseline condition than in the High-EF (t(37) = 10.72, $p < 0.01$, $d = 1.84$) and High-ToM (t(33) = 2.76, $p = 0.01$, $d = 0.35$) conditions. Participants also had a faster speech rate in the High-ToM condition than in the High-EF condition (t(35) = 9.40, $p < 0.01$, $d = 1.43$). The group by condition interaction was not significant, F(1.80, 71.82) = 0.27, $p = 0.74$

Discourse features and listener ratings—Results indicated that for both the TBI and CP groups, MST frequency in the High-ToM condition was significantly correlated with raters' judgments of social acceptability (TBI: r = −0.46, n = 19, $p = 0.05$; CP: r = −0.46, n =20, $p = 0.04$ with outliers removed, and r = −0.14, n = 22, $p = 0.54$ with outliers included) such that more frequent MST use was associated with more positive ratings (see figure 1).

Raters' judgments of appropriateness, however, were not significantly correlated with MST use in either the TBI ($r = -0.20$, $n = 19$, $p = 0.42$) or the CP group ($r = -0.43$, $n = 20$, $p = 0.06$ with outliers excluded, $r = -0.26$, $n = 22$, $p = 0.24$ with outliers included). Because the TBI and CP groups did not differ in dysfluency rate, data were collapsed across groups. There was a relationship in the expected direction (i.e. greater dysfluency = less positive ratings) for acceptability ratings, but this relationship was only significant with outliers excluded, $r = 0.31$, $n = 41$, $p = 0.05$, $r = 0.28$, $n = 42$, $p = 0.08$ with outliers included (figure 2). The relationship between dysfluency frequency and appropriateness ratings was also in the expected direction, but again was only significant with outliers excluded ($r = 0.31$, $n = 41$, $p = 0.05$, $r = 0.30$, $n = 42$, $p = 0.06$ with outliers included).

Implications and Conclusions

For decades researchers and clinicians have worked to capture and understand the social communication problems of adults with moderate-to-severe TBI. The present study extended these efforts by documenting social communication impairments in adults with TBI on an ecologically valid task. In the following sections we discuss results related to group and condition effects, then findings related to the predicted interaction of group by condition.

Group Effects

In this sample, participants with TBI used MSTs less frequently than their uninjured peers when discussing their opinions and those of others. This finding is consistent with those of Byom and Turkstra (2012) who reported that a group of men with TBI used MSTs at a lower rate than a comparison group. The current study extended this finding by demonstrating a significant link between MST use and perceptions of potential communication partners, as discourse samples with more MSTs were judged as more socially acceptable. While there has been anecdotal evidence that social language use affects social acceptance, to our knowledge this is the first empirical evidence of a direct link. If these findings are replicated when video recordings or actual conversational interactions are judged, it may suggest that changes in social language may explain some of the negative social outcomes experienced by individuals with TBI.

Unlike MST frequency, groups did not differ in dysfluency rate despite the TBI group's poorer EF test scores. This finding conflicts with prior reports of greater dysfluency in individuals with TBI (Ghayoumi *et al.*, 2015; Moran, Kirk and Powell 2012) and might be, in part, related to the discourse task's design. Participants completed the task in a quiet room and were provided with conversation topics. These supports might have helped participants compensate for EF impairments and thus such problems were not evident in their discourse. The groups might also have had similar dysfluency rates because this measure was not sensitive to EF impairments. McDonald et al. (2014) found that adults with TBI who had EF impairments generated fewer relevant details in their discourse task than adults without TBI, and that performance could be attributed, in part, to EF task demands. It is possible, therefore, that measures of discourse content may be more sensitive than dysfluency to EF impairments in social communication.

Despite null findings related to dysfluency, secondary analysis indicated that the TBI group spoke at a slower rate than the CP group. Slowed speech rate has been reported previously in individuals with TBI (Campbell and Dollaghan 1995) and this slowing has been attributed to a combination of motor control disruption and impaired cognitive-linguistic functioning (Campbell and Dollaghan 1995). In this study, participants with TBI did not have aphasia or fluency disorders and had either no or very mild dysarthria, so it is unlikely that slowed speech rate in the TBI group was the product of speech production problems, per se, and instead may indicate that the TBI group needed increased time to generate, organize, and monitor their responses to the discourse task prompts (Kowal, O'Connell and Sabin 1975).

Condition Effects

Participants in both groups used MSTs less frequently in the High-EF condition than in the baseline and High-ToM conditions, suggesting that increased EF demand reduced participants' ability to consider mental states and use them in their discourse, even when the ToM demand itself was low. Similarly, McDonald *et al.* (2014) found that EF demands influenced the ability to describe relevant details on a perspective-taking task. It is also possible that participants used fewer MSTs in the High-EF condition than in the baseline and High-ToM conditions because avoiding "and" and "the" affected not only EF demand, but cognitive load, in general. Participant responses to the manipulation check question indicated that they had to "think more" in the High-EF condition than in the Baseline condition, but this question did not probe EF demand specifically. If the High-EF condition was in fact more difficult than the other conditions, these findings suggest that discourse may be sensitive not to EF demands in particular, but instead to the general cognitive demands associated with a communication task.

Dysfluency rate did not differ across conditions, though condition order may have contributed to this finding. Participants completed the baseline condition first for each topic, and then later repeated their baseline answer without using the prohibited words for the High-EF condition. Avoiding "and" and "the" increased cognitive demand relative to the Baseline condition, as indicated by manipulation check responses and decreased MST use, but the effects on fluency may have been mitigated by practice effects from having previously answered the question in the baseline condition. Similarly, the High-ToM condition occurred after the baseline condition, allowing participants the opportunity to consider the topic, which may have reduced the task's cognitive demands, preserving fluency.

Speech rate did vary across conditions, as both groups spoke more slowly in the High-EF and High-ToM conditions than in the baseline condition. Slowed speech rate is associated with increased cognitive demand (Kowal, O'Connell and Sabin 1975) and in this study results may indicate that participants slowed their speech rate strategically in order to maintain fluency in the face of high cognitive demands. It is notable that reduced speech rate from baseline was not condition-specific, suggesting that speech rate may be sensitive to general cognitive load rather than specific EF or ToM demands.

Interaction Effects

Based on the vulnerability of ToM and EF to TBI, we hypothesized that dysfluencies and MST use in the TBI group would be affected only in high-demand conditions. This hypothesis was not supported, however, as group by condition interactions were not found for any of the discourse measures used in this study. This finding may mean that the task manipulations did not alter cognitive demand sufficiently, though this seems unlikely based on participants' responses to the manipulation check questions. It also is unlikely that the manipulations were unsuccessful because condition effects were found for both the High-EF (MST use and speech rate) and High-ToM conditions (speech rate). An alternative explanation is that instead of only being difficult for the TBI group, the task manipulations also challenged the CP group, resulting in similar discourse changes across groups. In this case, results could mean that individuals with TBI have social communication problems, even when demand is low, but also that their discourse is affected to a similar degree by changes in cognitive demand, as is that of their uninjured peers.

Implications

The aim of this study was to investigate the roles of EFs and ToM in the social communication of adults with TBI. We expected domain-specific effects, but results were more consistent with a domain-general, limited capacity framework than with either the Social Inference or the EF Hypotheses. In limited capacity frameworks (e.g. Baddeley and Hitch 1974), cognitive processes compete for a constrained set of general processing resources. Our findings were consistent with this account. Our initial hypotheses were based on evidence that ToM and EF are dissociable in individuals with TBI (Bach *et al.* 2000, Muller *et al.* 2010), but in retrospect both conditions required ToM and EFs, as participants reflected on their own mental states during the High-EF condition and, as in all perspective-tasking tasks, needed to inhibit their own thoughts in order to consider those of someone else in the High-ToM condition. Thus, despite our attempt to differentially manipulate EF vs ToM demands, results indicated that cognitive demand in general might have affected social communication more so than discrete increases in either of these cognitive functions. Participants slowed their speech rate in response to both the ToM and EF manipulations and MST use declined in response to increased EF demand. From a limited-capacity perspective, these discourse changes can be interpreted as consequences of participants' attempts to meet the overall cognitive demands of the discourse task, whether these demands included EF, ToM, or both in combination with other cognitive processes. It is important to note that group differences were found in both MST use and speech rate, suggesting that TBI may reduce the processing capacity available for social communication, or alternatively, that communication tasks may be more taxing for individuals with TBI than for their uninjured peers.

Clinically, these findings suggest that ToM deficits may be evident in social communication and can have consequences for how people with TBI are perceived and the likelihood that they will be socially accepted. More broadly, our findings of discourse changes with the cognitive demands associated with communication reinforce the importance of considering the communication task and associated cognitive demands when evaluating social communication performance of adults with TBI.

Limitations

A potential limitation of the current study was the relative lack of racial, geographic, and educational diversity of the sample. Nearly all participants self-identified as white, all were from the upper Midwest region of the United States, and most had completed at least some post-secondary education. Education-related socio-economic factors may play a role in discourse outcomes after TBI (Coelho 2002) and these factors should be considered in future research. It will be of interest to see if patterns observed here are consistent across sociodemographic groups, as poor social communication has been reported in adults with TBI worldwide (e.g. Breau *et al.* 2015, Rousseaux, Vérigneaux and Kozlowski 2010, Sainson, Barat and Aguert 2014). In addition, discourse raters were predominantly female college students, and likewise were a demographically limited sample. Raters and participants in the TBI and CP groups were similar geographically and educationally, so it is likely that they shared some standards for social acceptability, but the role of the rater's sex should be considered in future studies. Males and females might be expected to differ in their expectations for appropriate social behavior, but a recent study showed that male and female raters were similar in their judgments of the social communication of familiar adults with TBI (Despins *et al.* 2015)

This study also had limitations related to ecological validity. As with most studies of discourse, there was a tradeoff between ecological validity and experimental control. This was especially evident in the High-EF condition. While natural conversation requires speakers to inhibit irrelevant or inappropriate utterances, we asked participants to avoid target words rather tangential thoughts. It is possible that the EF demands of our task differed from those experienced in everyday interaction. Further, in all conditions, participants were provided with topics and clear instructions, which also limited ecological validity. In addition, all participants conversed with a female investigator who was scripted to provide only back-channel responses. Status and sex-based differences between individuals with TBI and their communication partners may have significant effects on participant communication behaviors (Stronach and Turkstra, 2008, Togher and Hand, 1998) and results may differ in interactions with other types of communication partners.

A further limitation of this study was that despite enrolling only adults who had sustained moderate-to-severe TBI, most participants in this study were very high functioning. While 14 of the 21 participants with TBI were unemployed at the time of participation, all but two had legal independence. Further, participants with TBI, on average, scored within the low-average range of published norms on the neuropsychological tests administered, suggesting rather high levels of cognitive functioning. It is possible that the discourse task manipulations may have had a greater effect on social communication in a sample of individuals with more severe EF or ToM impairments.

Conclusions

This study was designed to investigate social communication impairments and their underlying mechanisms in adults with TBI, and also to connect communication to judgments of potential communication partners. Results add to previous descriptions of discourse impairments in adults with TBI, specifically evidence of reduced MST use and slowed speech rate. A critical finding was that discourse behaviors negatively affected judgments of social acceptability by naïve raters. Results also added to the literature showing how manipulating task demands can affect discourse performance. Taken together, results support a domain-general, limited capacity framework for explaining the underlying causes of social communication problems in adults with TBI. In adopting such a framework, future work may take a broader approach to examine the overall cognitive and communication demands of social interaction rather than the individual contributions of discrete cognitive processes.

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What this paper adds

What is already known on this subject?

Social communication problems are common after traumatic brain injury (TBI). The underlying causes of social communication problems, as well as their social consequences for adults with TBI, however, remain unclear.

What this study adds

This study provides further evidence of social communication problems in the discourse of adults with TBI and demonstrates that the frequency of certain behaviors (i.e., dysfluency and use of words that reflect mental states) may affect how speakers are perceived by potential communication partners. This study also adds evidence that discourse is affected by the cognitive demand imposed by a communication task. Findings support the use of a domain-general framework to direct future research of the cognitive underpinnings of social communication after TBI. Results also add evidence of the importance of considering the cognitive demands of communication tasks during assessments of adults with TBI.

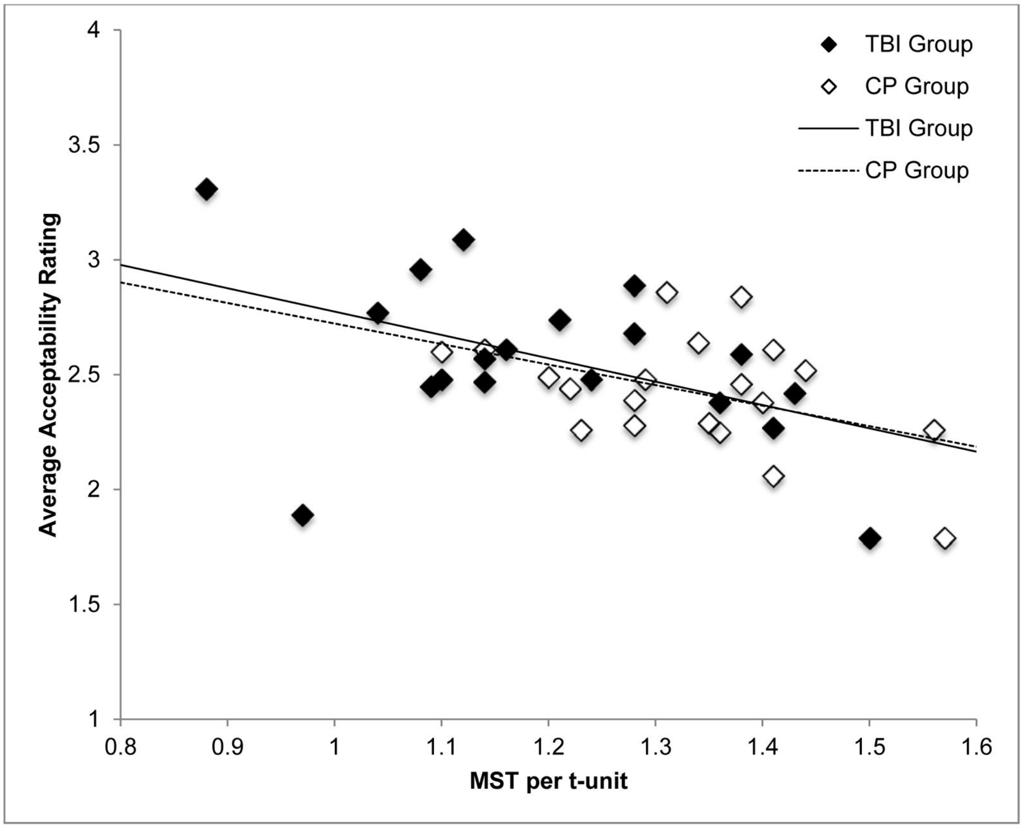

Figure 1.
Scatter plot of square root transformed MST frequency in the High-ToM condition and average acceptability rating.

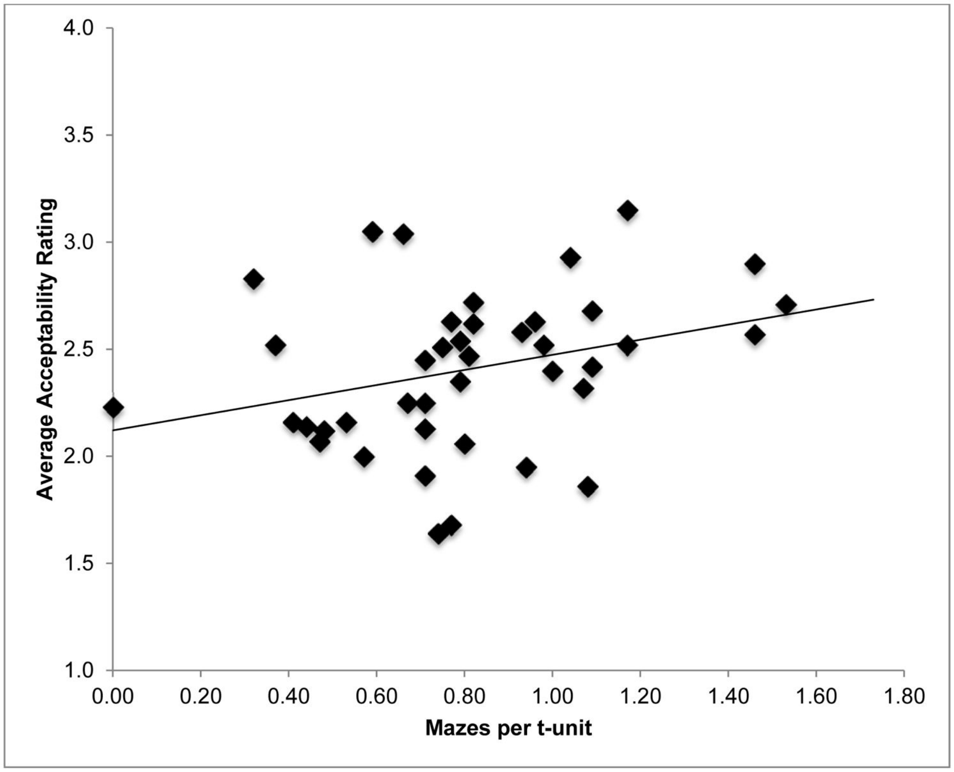

Figure 2.
Scatter plot of square root transformed maze frequency in the High-EF condition and average acceptability rating. All participants.

Table 1

Neuropsychological Test and Experimental Task Scores

	Group				Group difference	
	TBI (n = 21)		CP (n = 23)			
	Mean	SD	Mean	SD	t-test values	Cohen's *d*
Trails Letter Sequencing (seconds)	34.95	10.15	23.13	6.72	t(41) = 4.56, $p < 0.01$	1.37
Trails Switching time (seconds)	82.65	24.19	65.81	16.98	t(39) = 2.59, $p = 0.01$	0.81
Colors Inhibition/Switch Time (seconds)	70.50	15.89	53.70	10.11	t(41) = 4.19, $p < 0.01$	1.26
WAIS-IV PSI (standard score)	93.10	12.70	111.34	9.64	t(40) = −5.25, $p < 0.01$	1.62
CVLT-II Free recall (T-Score)	44.35	12.46	53.65	7.51	t(41) = −2.91, $p = 0.01$	0.90
VSIT (percent correct)	79.61	21.33	83.13	11.67	t(37) = −0.64, $p = 0.52$	0.20

Notes. WAIS-IV PSI = Weschler Adult Intelligence Test, Fourth Edition Processing Speed Index, CVLT-II = California Verbal Learning Test, Second Edition, VSIT = Video Social Inference Task.

Table 2

Discourse Features by Group

		TBI Group			CP Group		
		Baseline	**High-EF**	**High-ToM**	**Baseline**	**High-EF**	**High-ToM**
Total Words	Mean	461.81	283.00	398.24	392.43	189.00	353.91
	SD	269.42	174.10	226.57	327.89	144.82	287.06
	Range	96–1076	47–806	119–1082	73–1112	34–640	67–1179
TTR	Mean	0.61	0.54	0.47	0.51	0.60	0.52
	SD	0.76	0.11	0.10	0.12	0.11	0.10
	Range	0.33–3.90	0.37–0.81	0.31–0.69	0.31-.076	0.39–0.85	0.29–0.68
MST/t-unit	Mean	1.46	1.31	1.45	1.90	1.55	1.92
	SD	0.37	0.38	0.39	0.66	0.59	0.46
	Range	0.86–2.20	0.63–2.25	0.77–2.24	1.08–4.05	0.50–2.79	1.21–3.00
Mazes/t-unit	Mean	0.74	0.71	0.73	0.81	0.78	0.79
	SD	0.33	0.36	0.43	0.50	0.67	0.52
	Range	0.26–1.47	0.07–1.38	0.18–1.64	0.00–2.21	0.00–2.35	0.00–1.96
Words/minute	Mean	141.19	88.57	129.83	167.66	105.34	156.98
	SD	31.28	30.14	34.74	38.19	36.63	34.06
	Range	91.98–189.77	46.53–155.00	88.05–213.13	75.00–235.59	52.05–192.00	101.20–235.00